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CONTENTS

This report presents the following information.

Section I.

Summary of Technical Work

A. Accomplishments

1. Abstracts of papers presented by Institute personnel.

   a. "The Prediction of Transient Heat Transfer Performance of Thermal Energy Storage Devices" By M. Altman, D.P. Ross, and H. Chang

   Presented: National Heat Transfer Conference, August, 1963, Boston. To be published in A.I.Ch.E. Proceedings of Conference. A.I.Ch.E. Preprint No. 56

   ABSTRACT

   This paper discusses the analytical prediction of the performance of energy storage devices which utilize the heat of fusion of materials.

   Solar powered electrical generators depend on some form of energy storage for operation in the "dark" portion of their duty cycle. Energy can be stored either electrically, as in batteries, for instance, or as heat energy, as latent heat of fusion, etc.

   Thermal energy storage is of importance for two main reasons. One, it minimizes thermal cycling, and two, in the case of orbiting space vehicles it is found that savings in weight occur when thermal energy storage is used, rather than batteries.

   This paper is concerned with only one aspect of heat of fusion energy storage, namely the prediction of heat transfer performance.

   A fairly simple model using one dimensional analysis was developed. Heat entered through one wall causing the ceramic material to eventually melt and the position of the solid-liquid phase boundary was computed as a function of time. Various heat inputs and wall thicknesses were used. Computation was by an IBM 7090 digital computer.

b. "Approximate Method for Calculating Magnetohydrodynamic Boundary Layer and Heat Transfer of a Slightly Conducting Fluid past a Cylindrical Body" by H. Lien and H. Yeh

To be published in Journal of the ASME. AIAA Preprint No. 63-202

ABSTRACT

An approximate method for the solution of the laminar magneto-hydrodynamic boundary layer and heat transfer has been developed. This method can be applied to the problem of an incompressible flow past an arbitrarily shaped cylindrical body in the presence of a magnetic field normal to the axis of the cylinder. (It can also be used for a compressible case when Howarth-Dorodnitsyn variables are introduced.)

Based on this method, calculations are made for the case of flow around a circular cylinder. First, the velocity and pressure distributions in the inviscid flow (with a magnetic field) is obtained. These results, then, are used to solve the viscous and thermal boundary layer equations. Detail calculations have been made on the influence of the Reynolds number, Prandtl number, Eckert number, and the magnetic interaction parameter on the point of separation, the boundary layer thickness, the shear stress at the wall, the velocity and the temperature profiles, and the rate of heat transfer.

c. "The Binary Eutectic as a Thermal Energy Storage System: Equilibrium Properties" by G. R. Belton and Y. Krishna Rao

Presented: National Heat Transfer Conference, August, 1963, Boston

ABSTRACT

The method is reviewed for the calculation of heats of fusion of binary eutectic systems of metals or salts from the available thermodynamic data. A preliminary survey has been made to find metals, metallic compounds and binary systems of these

substances which could serve as constant temperature heat reservoirs for thermal energy storage.

d. "The Optimization of MHD Generators with Arbitrary Conductivity" by H. Yeh and T.K Chu

To be presented at ASME Winter Annual Meeting, Philadelphia, 1963. To be published in Journal of ASME.

ABSTRACT

This analysis is based on the one-dimensional, inviscid, non-heat-conducting flow equations of an ionized gas (whose electrical conductivity is in general a function of pressure and temperature) flowing through a channel for the purpose of the extraction of electrical power. The problem is: given the inlet conditions and a fixed channel length, what should be the distribution of channel cross-sectional area (and hence of all other gas properties) in order to extract maximum power? This variational problem is solved in the present paper by means of a computational procedure based on the "method of gradients". The method developed here can be applied to either a continuous-electrode generator or a segmented-electrode generator, and with tensor conductivity.

2. Laboratory

A 35 feet by 50 feet area which had originally been used as a machine shop instruction area has been made over into a modern laboratory facility by the Towne School of Civil and Mechanical Engineering. This laboratory accommodates all of the experimental programs in progress.

One section of this common facility consists of a combination electro-chemical and bacteriological laboratory, used for the investigation of biological fuel cells. This section is completely operational.

The second section of the laboratory houses the metallurgical apparatus for the work on thermal energy storage. This area is also fully operational.

The third section is in the process of being equipped for the heat transfer testing of thermal energy storage materials. Completion of this facility is expected by November 1, 1963.

A fourth portion of the laboratory is used for a magnetohydrodynamic arc generator, to be used in studies of non-equilibrium ionization of gases. This area is fully operational.

A new section, equipped for general plasma studies is still in the planning stages.

A complete list of available apparatus is appended to this report.

It is planned to assemble a "Capabilities" report, describing the types of investigations which may be undertaken with the apparatus in our possession. This report will be forwarded to NASA by the end of calendar 1963.

B. Work in Progress and Planned

1. Thermal Energy Storage

a. Materials Synthesis - Dr. G. R. Belton

The systems finally decided upon for investigation as possible thermal energy storage media are

(1) $LiF + MgF_2$, $LiF + NaF$ and $NaF + MgF_2$

(2) $Li_2O + CaO$, $Li_2O + MgO$, $Li_2O + BeO$, $BeO + CaO$, $BeO + MgO$, $Li_2O + BeO + MgO$ and $Li_2O + BeO + CaO$

A wide range of fusion temperature is offered by this set of systems.

The correct interpretation of the transient properties of these systems will depend upon the availability of reliable equilibrium data. Consequently, the aim of these initial investigations is the determination of the thermodynamic properties of each system. It is intended to determine:

(a) the phase equilibria in the interesting areas of each binary system (eutectic region) by differential thermal analysis and metallographic and X-ray techniques;

(b) the heats of fusion of eutectic and other compositions by use of an isothermal dropping calorimeter; and

(c) the partial molar properties of the liquid solutions, initially by means of electro-motive force measurements.

An apparatus suitable for carrying out differential thermal analyses at temperatures up to 1750°C has been constructed. The apparatus consists of a vertical platinum-40% rhodium wound furnace fitted with a 42" long reaction tube. The furnace temperature is controlled by a proportional acting controller operating through a controlled silicon rectifier. Cams have been made which permit desired heating and cooling rates to be achieved. The samples for differential thermal analysis are supported within a small platinum-rhodium coil and it is so arranged that one junction of the differential thermocouple is located within the sample. The differential e.m.f. is recorded on a strip-chart recorder after passing through a D.C. amplifier. The furnace temperature is recorded separately on another strip-chart recorder capable of accurate calibration. Time marks are made simultaneously on each chart by means of an auxiliary electrical unit.

An isothermal diphenyl ether dropping calorimeter has been designed which shall be capable of measuring heat content or temperature up to 2100°C.

The isothermal calorimeter employs the fact that diphenyl ether experiences a volume expansion upon fusion. The unit is composed of a tantalum resistor heated furnace and a calorimetric well. The calorimetric well is a copper tube extending from the bottom of the furnace case and has an inconel section welded in to reduce heat loses by conduction. The well is surrounded by a double walled Dewar flask which contains diphenyl ether and mercury. The Dewar flask is then surrounded by a water bath maintained at the melting point of diphenyl ether. Before starting a run a mantle of solid diphenyl ether is formed on the well by introducing dry ice into it. Then the sample is brought to the required temperature in the furnace and dropped through a water-cooled gate into the well. The heat released will melt the diphenyl ether and the resulting volume expansion displaces the mercury. By measuring the amount of mercury displaced, the heat released can be calculated.

The isothermal calorimeter is expected to go into operation in a few weeks.

The measurement of the activities in the liquid fluoride systems will be carried out by an e.m.f. technique. The design and construction of the necessary cells is at present underway.

b. Heat Transfer Studies - Dr. M. Altman

A high vacuum chamber for the testing of high heat of fusion materials at extremely high temperatures was designed in conjunction with the Elion Instrument Company of Burlington, New Jersey. The vacuum chamber is capable of better than 10^{-8} mm of mercury and also able to pressurize with an inert gas to several psi above atmospheric pressure. Pump down is accomplished in three successive stages by a mechanical pump, diffusion pump, and an ion pump. The test modules containing the material to be investigated are being designed.

The attached picture shows the vacuum chamber and the pumps as well as the overhead traveling lift for removal of the bell jar and modules. Elion underwent an unexpected management reorganization and thus the completion of the apparatus was delayed. However, the equipment should be in the laboratory and operating by November 1, 1963 at the latest.

2. Plasma Physics

a. Magnetohydrodynamic Power - Dr. H. Yeh

In the past year, we have completed the investigation on two of the problems discussed in our last progress report. These two problems were:

(1) A general but workable method for calculating the boundary layer and heat transfer of a magnetohydrodynamic flow under arbitrary pressure, velocity, and magnetic field distributions in the direction of flow. Such a method will enable us to estimate the important factor of the amount of

heat transfer between the fluid and the wall in an MHD generator. This work was presented and published in Reference 1.

(2) The optimization of the distribution of MHD channel cross-sectional area (and hence of all other gas properties) in order to extract maximum power. This analysis can be applied to either a continuous-electrode generator or an infinitely-segmented-electrode generator, and with tensor conductivity. This work has been scheduled for presentation and publication in Reference 2.

With the completion of the above two problems, emphasis has now been shifted to the following:

(1) The spectroscopic measurements of electron and gas temperatures in an argon plasma jet when non-equilibrium ionization exists. (Since this phase of the work will be covered by Dr. Gottschlich in another section of this status report, it will not be repeated here.)

(2) The measurement of gas temperatures by means other than spectroscopic. Remote possibilities exist, for instance, by using calorimetry, heat transfer gage, or Langmuir probe.

None of these devices would be easy to apply or to analyze, but nonetheless we are making feasibility studies with a completely open mind.

(It is known, for instance, that the Debye shielding length on a Langmuir probe is dependent primarily on the ion temperature rather than the electron temperature. But how to make use of this phenomenon in a collision-dominated plasma is a most vexing problem.)

(3) Certain overall characteristics that may occur in a channel flow with non-equilibrium ionization. Since the electron heating is dependent on the local current density, the conductivity as well as the degree of ionization will also be dependent on current density. But current density itself is dependent on conductivity. Hence there is a self-feeding mechanism which may result in a number of interesting consequences. We are cooperating with other workers on this problem.

(4) In connection with the experimental investigation under Item 1, it is planned to make a detailed study of the theoretical basis and the physical mechanism of the non-equilibrium, steady-state ionization for our case of an

argon gas seeded with potassium. Involved in such a study are the rate processes of ionization, recombination, excitation and de-excitation. The degree of ionization and conductivity can in principle be calculated if the cross-sections for these processes can be assumed. We plan to look into this problem with the final objective as to how well the Saha equation can be used to determine the degree of ionization for the parameters involved in our experiments.

REFERENCES

1. Lien, Hwachii and Yeh, Hsuan, "Approximate Method for Calculating Magnetohydrodynamic Boundary Layer and Heat Transfer of a Slightly Conducting Fluid Past a Cylindrical Body", presented at the American Institute of Aeronautics and Astronautics Summer Meeting in Los Angeles, California, June 17-20, 1963. AIAA Preprint No. 63-202.

2. Yeh, Hsuan and Chu, Tsu-Kai, "The Optimization of MHD Generators with Arbitrary Conductivity", scheduled for presentation at the ASME Annual Meeting in November, 1963.

b. Non-Equilibrium Ionization - Dr. C. Gottschlich

The major pieces of purchased equipment not yet delivered are the spectrophotometer, expected about October 15 and an electronic recorder, expected in November. Also, undelivered are a quartz tube test section and tungsten electrodes. Delivery is uncertain on the latter two because of fabrication problems.

No difficulties have been encountered with fabrication of equipment in our shop. It appears that the shop will be finished with our apparatus within about a month. This corresponds fairly satisfactorily with the delivery schedule of our purchased equipment.

Unless unexpected difficulties arise the apparatus should be assembled and partial tests of its satisfactory operation should be completed by the end of 1963. Before the experimental measurements can be made some theoretical calculations will have to be made on the high temperature properties of potassium-argon systems. This is necessary so that the spectrophotometric measurements may be interpreted in terms of the plasma composition and the electron temperature.

A major uncertainty that exists is whether our proposed method of measuring the gas temperature will work. We propose to add a trace of a diatomic gas to the argon stream and measure the intensity distribution of the rotational lines that will be formed. The intensity distribution can be interpreted in terms of the gas temperature. If this method fails, we shall consider adding a trace of iron atoms to the plasma and measure the Doppler broadening of certain shielded electronic transitions. This has the disadvantage that interferometric measurements will have to be made in order to obtain adequate spectral resolution of the narrow lines produced. A second possibility is to measure the average enthalpy of the plasma leaving our apparatus with a calorimeter. This has the disadvantage that local values of the gas temperature will not be directly measurable. As measurements of rotational line intensity distributions have been made successfully in flames we are at present optimistic.

We must also make measurements of the local values of the plasma electrical conductivity. Our proposed method is to measure the total current in the test section by means of an ammeter and to measure the electric field distribution in the test section by means of electrodes installed in the wall. Then from the simultaneously measured temperature distribution in the apparatus we shall be able to infer the local values of the electrical conductivity. This will complete the set of measurements needed to compare the experimental observations with a theorectical analysis of the apparatus.

As the experiment is a complex one we feel that it will require at least a year to complete it and to make a satisfactory interpretation of our observations.

c. Thermionic Energy Conversion - Dr. L. Zelby

The effort during the period covered by this progress report was directed primarily to literature search, and qualitative analysis of the hollow cathode. In view of the feasibility study on such a device for energy conversion, other reported results were compared with it.[1] The only reasonable comparison can be made on current densities vs. cathode to anode voltage. Consequently, the current density is used here as a figure of merit. Data at 900^{o}C are compared and shown in Table I. This comparison indicates considerable spread in reported values of current densities, which now ought to be investigated with respect to the geometry and material of the cavity. Theoretical analyses of

TABLE I

REFERENCE	V ANODE VOLTS	J_{ma/cm^2}	V volts	J_{ma/cm^2}	V anode	J_{ma/cm^2}
1 (probe anode)	-1	.07	0	.5	1	6
1 (grove cathode)	-	-	.1	7	10	50
2	-	-	1	45	10	100
3	-1.2	1	0	50	-	-
4	-	-	1	2	10	60
5	-	-	1	5×10^3	10	10×10^3
6	-	-	0	300	10	600

such nature have been attempted, indicating a multi-valued solution for the case of zero field emission[7].

Some free-hand field plots of simple hollow cathode configurations have been made, indicating that a voltage minimum due to space charge may form behind the plane of the orifice, so that there should be a negligible retarding field in the inter-electrode region. Sandor arrived at an essentially analogous conclusion regarding virtual cathode formation[6].

It is evident that for best results, a non-symmetrical situation within the cathode is desired. This was confirmed by various discussions[8].

In view of the available data, it is contended that some further studies of the hollow emitter be made to establish definitely its potential as an energy conversion device. Consequently, it is planned to investigate experimentally several simple cylindrical hollow cathodes with various degrees of asymmetry, mechanical and/or thermodynamic.

Analysis of current-voltage characteristics of such a device will be initiated including the effects of the space-charge field. It will be also attempted to evaluate the integral, previously reported, relating to electron flow between inclined plates.

Several trips are planned to Lewis Research Center for consultations with Dr. Breitweiser regarding the shape and manufacture of the cathodes, as well as data reduction.

REFERENCES

1. I. Brodie and A. Niewold, "Feasibility of the use of hollow cathodes for thermionic energy conversion," ASD-TR-61-723; June, 1962
2. K.M.Poole, "Emission from hollow cathodes," J. Appl. Phys., vol. 26, No. 9 pp. 1176-1179; September, 1953
3. A.W.Bright and J.S.Thorp, "Measurements of retarding Potential on the hollow cathode," Nature, vol. 176, No.4492; pp.1079-1080; December, 1955
4. M.L.Babcock, D.F.Holshouser and H.Von Foerster, "Diode characteristics of a hollow cathode," Phys.Rev., Vol.91, p. 755, August, 1953
5. E.M.Dubinina and M.B.Pit'eva, "On some characteristics of electron emission from hollow cathodes," Radiotekhnika i Elektronika, vol. 8, pp. 1261-1266; 1960
6. A.Sandor, "Emission from miniature hollow cathodes," Proc. IEEE, vol. 108, pt B, pp. 90-96; January, 1961
7. I.Brodie and A.Niewold, "Zero field emission from thermionic hollow cathodes," J. Appl. Phys., vol. 33, No. 11, pp. 3328-3334, November, 1962
8. R. Breitweiser, personal communication

d. Plasma Physics - Dr. G. L. Schrenk

Dr. Schrenk has joined us only a few weeks ago, and for that reason only his research plans are discussed below.

Discussions were held with various members of the Institute pertinent to formulation of research plans. It was decided to do research work on the plasma diode--specifically, to investigate the plasma diode and all its various modes of operation. Initially this work will all be theoretical. It is felt that significant contributions can be made toward understanding the physics of the plasma diode.

Literature research has been initiated. The literature is overflowing with papers on the various aspects of plasma diodes.

During the past year considerable work was done on a generalized theoretical model of a cesium plasma diode. This model applies to a plasma diode whenever a fully randomized plasma is formed in the interelectrode spacing in both ion rich and electron rich conditions. This model takes into account plasma resistivity, surface ionization, and volume ionization and recombination effects. A phenomenological macroscopic approach is used to formulate the set of eleven simultaneous equations that describe this model. During the past year extensive numerical work has been carried on various refined versions of these equations on an I.B.M. 7090 computer. Work is in progress on the 15-th computer deck. This large number of decks has been necessary for two reasons--refinements in model and difficulties in developing solution techniques to handle eleven simultaneous non-linear equations.

During the past month several successful solutions have been obtained from the latest deck. (Approximately 30 min. on an I.B.M. 7090 computer are required per current-voltage curve.) Work is continuing to obtain additional solutions for various input conditions and to compare theoretical predictions with experimental results.

Extensive literature research on plasma diodes will continue. The present status of understanding of the plasma diode and its various modes of operation is one of chaos. The literature is full of papers; however, very few papers really contain any significant contributions. From this literature research, it is planned to write a review paper on the present state of the field.

In this paper it is planned to collect together significant contributions to date, classify various approaches used, and give some concrete direction to future research in this field. Present theoretical efforts seem to have little direction and various groups seem to be isolated with almost no understanding of one another's ideas and approaches.

It is also planned to carry out original research work to investigate the plasma diode and all its modes of operation. Initally this work will be theoretical in nature. Phenomenological macroscopic models will be used initially to aid in understanding the various modes of operation. These models will not be simplified for mathematical reasons--they will be general models that conform to physical reality. (Hence considerable numerical work will probably have to be done to solve these models.) Subsequently, more detailed microscopic work will probably be carried out in various problem areas. Some of these problem areas can already be anticipated--others will develop from the phenomenological macroscopic analysis work.

e. Biochemical Fuel Cells - Dr. J. O'M Bockris

In order to obtain basic information concerning the characteristics of biochemical fuel cells, resting cells of Escherichia coli capable of producing hydrogen from formic acid were selected for study.

Before electrochemical aspects could be considered, it was necessary to conduct a study of biochemical or biological systems.

Since information concerning the optimum pH and temperature of hydrogen evolution from formate by resting cells of Escherichia coli is readily available in the literature, it remained to determine optimum substrate concentration, optimum cell concentration, and the time dependence of the rate of hydrogen production.

The optimized hydrogen producing resting cell system will be applied to an appropriate fuel cell so that the characteristics of direct and indirect fuel cells can be compared.

Resting cell preparations of Escherichia coli ATCC8739 were obtained by growing cells in deep culture using a medium consisting of 1% glucose, 0.2% yeast extract, 0.2% peptone, 0.8% nutrient broth, 1.4% Na_2, and 14% KH_2PO_4. The cultures were incubated at 37°C for 14 hours. The cells were harvested, washed and suspended in saline.

Because the enzyme responsible for hydrogen production, formic dehydrogenase, is an induced enzyme, the preparation of resting cells requires a great deal of attention.

The specific activity of the enzyme system is defined in terms of its Q_{H_2} value-the volume of H_2 evolved per unit time, per unit weight of dry bacteria cell, in units of $[\mu l. mg^{-1} h^{-1}]$.

In order to obtain Q_{H_2} values comparable to those reported in the literature it is necessary that the inoculum be passed from an agar slant to a broth culture and again to another broth culture. 100 cc of the final broth culture which is incubated for 24 hours at 37°C is used to inoculate the six liter culture.

The resting cell preparations are stored under nitrogen at 4°C.

An attempt was made to induce formic dehydrogenlyase at higher Q_{H_2} levels by replacing glucose with glycerol in the growth medium containing formic acid. Since poor growth of _E. coli_ resulted under anaerobic conditions with glycerol as the energy source, it was decided to postpone an investigation into methods for inducing higher amounts of formic dehydrogenlyase in *E. coli* for the present.

Using conventional manometeric techniques, it has been determined that a concentration of 100 μ M of sodium formate will support the highest production rate of hydrogen over a period of 6 hours. Unfortunately, at all concentrations of formate studied, Q_{H_2} decreases with time. The specific activity (Q_{H_2}) changes also with bacterial concentration, and was found to be a maximum in the range of 1.5 - 3 mg cc^{-1}. However, the total hydrogen activity per unit volume of solution can be usefully increased, by increasing the bacterial concentration to approximately 10 mg/cc.

Work is presently in progress to study hydrogen producing activity at constant formate concentration. The purpose of this study is to determine exactly whether decrease in the rate of hydrogen production is a function of time or substrate concentration.

After completing the above study, the hydrogen producing system will be scaled up for use in indirect and direct biochemical fuel cell studies.

Comparisons of the characteristics of the indirect and direct fuel cells will be made, and the mutual effects of the biological and electrochemical systems evaluated. In particular, it is intended to determine whether the rate determining step is slow production of H_2 by the enzyme or its slow oxidation at the electrode. The major effort will subsequently be concentrated in studying that part of the system which controls the overall rate.

Section II.

List of Institute Participants

NAME	TITLE	SCHOOL	ACTIVITY
Dr. Manfred Altman	Director	Towne School of Civil and Mechanical Engineering	Thermal Energy Storage
Dr. John Brainerd	Member, Advisory Committee	Moore School of Electrial Engineering	
Dr. John Hobstetter	Member, Advisory Committee	School of Metallurgy	
Dr. Robert Maddin	Member, Advisory Committee	School of Metallurgy	
Dr. John Bockris	Senior Member	Electrochemistry	Biochemical Fuel Cell
Dr. Geoffrey Belton	Senior Member	School of Metallurgy	Thermal Energy Storage
Dr. Hsuan Yeh	Senior Member	Towne School of Civil and Mechanical Engineering	Magnetohydrodynamics
Dr. Leon Zelby	Senior Member	Moore School of Electrial Engineering	Thermionics - Plasmas
Dr. Chad Gottschlich	Senior Member	Towne School of Civil and Mechanical Engineering	Plasma Diagnostics
Dr. R. Sharma	Senior Associate	Towne School of Civil and Mechanical Engineering	Thermal Energy Storage
Dr. George Schrenk	Senior Associate	Towne School of Civil and Mechanical Engineering	Thermionics - Physics
Dr. Joseph Gots	Consultant	Electrochemistry	Microbiology

(continued)

NAME	TITLE	SCHOOL	ACTIVITY
Dr. Eliezer Gileadi	Project Supervisor	Electrochemistry	Electrochemistry
Han Chang	Research Fellow	Towne School of Civil and Mechanical Engineering	Thermal Energy Storage
Richard Blasco	Research Fellow	Towne School of Civil and Mechanical Engineering	Biochemical Fuel Cell
Krishna Rao	Research Fellow	School of Metallurgy	Thermal Energy Storage
Tau Kai Chu	Research Fellow	Towne School of Civil and Mechanical Engineering	Magnetohydrodynamics
Michael Kaplit	Research Fellow	Moore School of Electrial Engineering	Thermionics
Daniel Ross	Research Fellow	Towne School of Civil and Mechanical Engineering	Thermal Energy Storage
William Frazier	Research Assistant	Towne School of Civil and Mechanical Engineering	
Rex Downie	Business Administrator	Towne School of Civil and Mechanical Engineering	
Frances Yobeck	Secretary	Towne School of Civil and Mechanical Engineering	
Margaret Moore	Secretary	Towne School of Civil and Mechanical Engineering	
Donald Gentner	Machinist	Towne School of Civil and Mechanical Engineering	

Section IV.

Status of Ph. D. Candidates

Chang, Han

Mr. Han Chang is a Graduate of the Polytechnic Institute of Brooklyn where he received his Mechanical Engineering degree (Summa Cum Laude) in 1956. From 1956 to 1961 he participated in a rigorous employee training program in the General Electric Company involving advanced engineering problems in turbine and heavy switch gear design. Mr. Chang is presently taking his Doctoral preliminary examinations and expects to receive his Ph. D. in Mechanical Engineering in 1964.

Blasco, Richard

Mr. Richard Blasco holds an M.A. Degree in Biology which he received in 1961 from Clark University. He received his Bachelor degree in Bacteriology in 1957 from the University of Connecticut. Prior to commencing his work at the Institute, Mr. Blasco was employed as a Scientist-Biochemist at the Electric Boat Company, Groton, Conn. Mr. Blasco expects to receive his Ph. D. degree in 1965 in Molecular Biology.

Rao, Y. Krishna

Mr. Y. Krishna Rao holds a B.S.C. in Metallurgical Engineering from Banaras Hindu University, Banaras, India which he received in 1962 with lst Class Honors. He has been with the Institute since his graduation and expects to receive his Ph. D. degree in Metallurgical Engineering in 1964.

Chu, Tsu Kai

Mr. Tsu Kai Chu holds a B. S. Degree in Agricultural Engineering from National Taiwan University, Taiwan, which he received in 1955. In 1958 he received a Masters Degree in Civil Engineering from the University of Washington, and in 1961 a M. S. in Civil Engineering from Massachusetts Institute of Technology. Mr. Chu has published three papers on various topics of hydrodynamics. Mr. Chu expects to receive his Ph. D. in Mechanical Engineering in 1964.

Kaplit, Michael

Mr. Michael Kaplit received a Masters Degree in Electrical Engineering in 1962 from the Moore School at the University of Pennsylvania after graduating in 1961 from the Massachusetts Institute of Technology with an S. B in the same field. Excerpts from Mr. Kaplit's Masters Thesis entitled "Power Transfers Among Three Parallel Harms-Goubau Lines" will be published in the Journal of the Franklin Institute. Mr. Kaplit expects to receive his Ph. D. in Electrical Engineering in 1965.

Ross, Daniel

Mr. Daniel Ross graduated in 1952 from City College of New York, receiving a Bachelor of Science Degree in Electrical Engineering. The following year he received a Masters Degree in Electrical Engineering from Columbia University which was followed by a year's study at the Oak Ridge School of Reactor Technology. Mr. Ross then held a position as Special Lecturer in Nuclear Engineering at Case Institute of Mechanical Engineering which he left in 1958 to take a position as Senior

Ross, Daniel - (continued)

Engineering Specialist with Thompson Ramo Wooldridge where he worked with energy conversion techniques as applied in Space Power problems. He then held a position as a Consulting Engineer for General Electric Company, Missle and Space Division, in the Advanced Nuclear Systems section. Mr. Ross has had published ten technical papers. He expects to receive his Ph. D. in Mechanical Engineering in 1964.

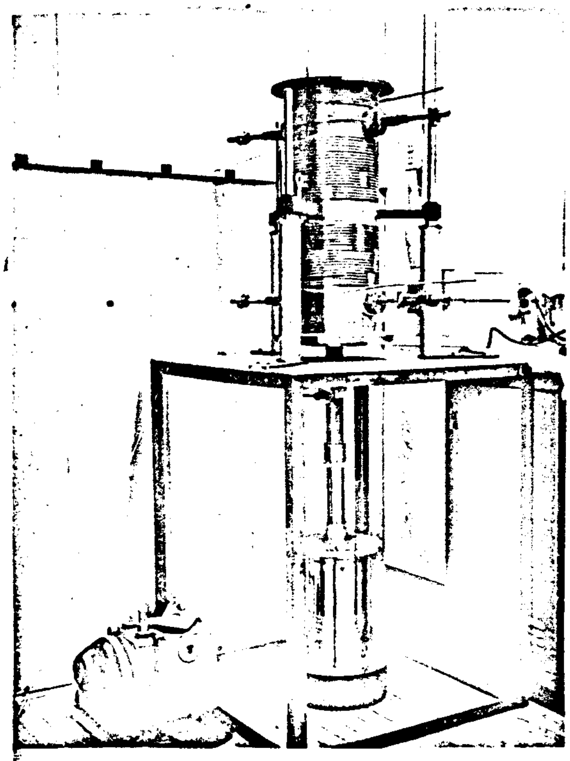

Fig. 1. Isothermal Calorimeter for measuring heats of fusion.

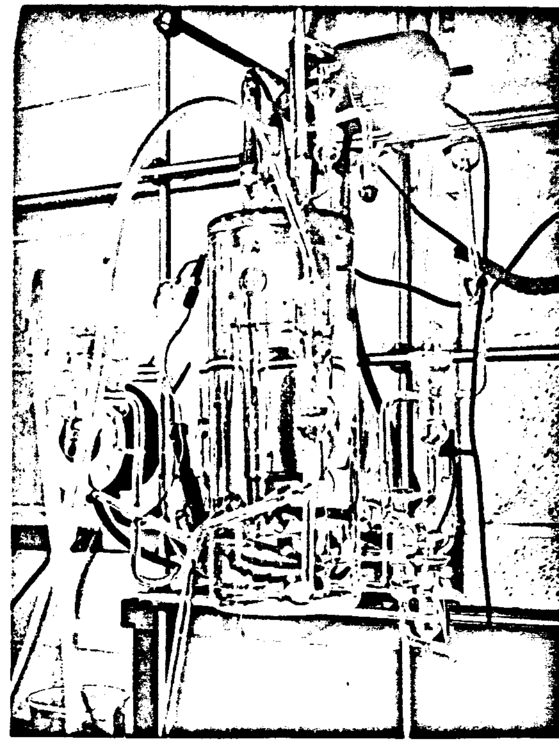

Fig. 2. Electrochemical cell for investigating Biological fuel cell characteristics.

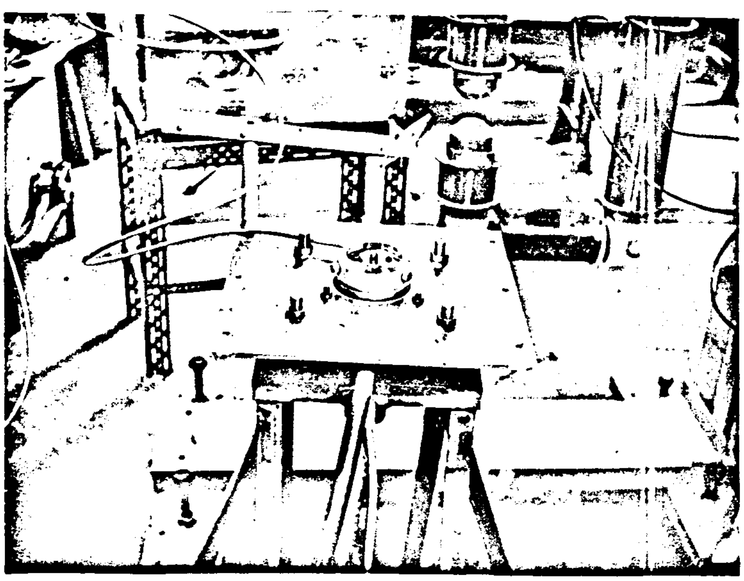

Fig. 3. Plasma jet for MHD investigations.

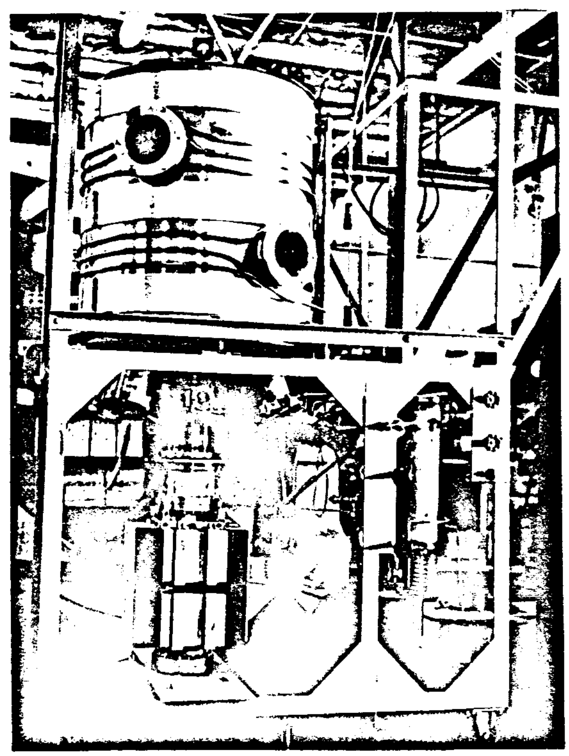

Fig. 4. High vacuum chamber for investigating transient heat transfer characteristics.

LIST OF EQUIPMENT

1	Constant Voltage Transformer
1	Speedomax H.A.Z.A.R. Recorder
1	Potentiometer
1	Still
1	Autoclave
1	Gramatic Mettler Balance
1	Walk in Frigid Room
1	Centrifuge
1	Incubator
1	Sartorius Balance
1	Isothermal Dropping Calorimeter (specially fabricated)
2	Platinum-Rhodium wound Furnaces
1	Barber-Coleman "Chronotrol" Temperature Regulator
1	Speedomax H.A. Recorder
1	High-Vacuum Chamber-Induction Furnace Unit (specially fabricated)
1	Princeton JB-5 Amplifier
1	Device for Remotely-Controlled "Seeding" of Plasma Jet with Liquid Potassium (specially fabricated)
1	Spectrophotometer